

The Effect of Light on Amorphous Silicon Thin Film Transistors based on Photo-Sensor Applications

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ABSTRACT

We have investigated the effect of light on amorphous silicon thin film transistors based photo-sensor applications. We have analyzed the instability caused by electrical gate bias stresses under the light illumination and the effect of photo-induced quasi-annealing on the instability. Threshold voltage (V_{TH}) under the negative gate bias stress with light illumination was more decreased than that under the negative gate bias stress without light illumination even though V_{TH} caused by the light-induced stress without negative gate bias was shifted positively. These results are because the increase of carrier density in a channel region caused by the light illumination has the enhanced effect on the instability caused by negative gate bias stress. The prolonged light illumination led to the recovery of shifted V_{TH} caused by negative gate bias stress under the light illumination due to the recombination of trapped hole charges.

INTRODUCTION

The hydrogenated amorphous silicon thin film transistors (a-Si:H TFTs) have attracted considerable attention as uniform and cheap devices for various displays [1-2]. The a-Si:H TFTs have been normally used as switching devices of liquid crystal display. In this application, a-Si:H TFTs have been blocked by using the black matrix which prevents the light from being transmitted between the pixels. Hence, the effect of light including the instability caused by light induced stress on a-Si:H TFTs has not been needed to consider. However, a-Si:H TFTs are being applied in photo-sensor applications such as touch-screen technology recently because a-Si:H TFTs exhibit high photoconductivity. Since a-Si:H TFTs as photo sensors have to be exposed to light illumination directly, the effect of light on a-Si:H TFTs has become an issue.

It has been reported that a-Si:H TFTs have the unstable characteristics such as threshold voltage (V_{TH}) shift and sub-threshold slope (S.S.) change when prolonged electrical bias stress to the gate electrode was applied [3-6]. The mechanisms to explain the instability caused by electrical gate bias stresses on a-Si:H TFTs have so far been studied

[3-6].

In particular, the unexpected instability of a-Si:H TFTs due to the effect of light under electrical gate bias can lead failure in the operation for demanding photo-sensor applications. Nonetheless, the mechanism to explain instability caused by light-induced stress under electrical gate bias has not been investigated enough to be applied to photo-sensor applications. Recently, we have researched the ways to recover the instability caused by negative gate bias stress using the light-induced condition.

The purpose of our work is to investigate the effect of light on amorphous silicon thin film transistors based on light-sensor applications. We have analyzed the instability caused by electrical gate bias stresses under the light illumination and the effect of photo-induced quasi-annealing on the instability.

EXPERIMENT

We fabricated the inverted-staggered bottom gate a-Si:H TFTs by using etch-back process. First, a 250 nm thick double-layer gate metal (Mo/AlNd) was deposited by DC sputtering on a glass substrate. 450nm thick SiNx gate insulator layer, 200 nm thick a-Si:H active layer and 50 nm thick N+ doped a-Si:H layer were deposited by plasma-enhanced chemical vapor deposition (PECVD) in turn. After active island patterned, a 450 nm thick triple-layer source and drain electrode (Mo/AlNd/Mo) was deposited by sputtering. The 105 nm N+ doped a-Si:H layer between the source and drain electrode was dry etched to form the etch-back-type channel after patterning the source and drain electrode by a wet etching. A 200 nm thick SiNx was deposited for a passivation. Finally, after contact holes were formed, an indium tin oxide (ITO) electrode was deposited and patterned. The dimension of a-Si:H is 200 $\mu\text{m} \times 5 \mu\text{m}$.

The experiment temperature was 333 K. The source of light had luminance of 20,000 lx. The voltage between the drain and source electrode was fixed as 0V. The stress time was 20,000 seconds. The a-Si:H TFTs samples were an-

nealed at 200°C for 30 minutes before experiments. The measurements were performed under both dark (0 lx) state and illuminated (20,000 lx) state.

RESULTS AND DISCUSSION

After the light-induced stress without electrical gate bias was applied to a-Si:H TFT, figure 1 shows that V_{TH} was increased from 1.08 V to 3.42 V. In addition, S.S. was increased from 0.80 V/dec to 1.31 V/dec. V_{TH} shift and S.S. change caused by light-induced stress on a-Si:H TFTs could be a result of Staebler-Wronski effect (SWE) [7-8]. The SWE effect is caused by the defect creation of dangling-bond broken near mid-gap at the interface between a-Si:H layer and gate insulator. Generated defect states slow down the movement of the Fermi level toward the conduction band. It was shown as V_{TH} increase and S.S. increase of I-V transfer curve. In addition, the characteristic of self-recovery after light-induced stress was investigated. As shown in figure 1, I-V transfer curve after keeping floating-state (no contact, no heat) for 20000 seconds was hardly changed. It supports that generated defect states are hard to be self-recovered without thermal annealing as reported [4-5].

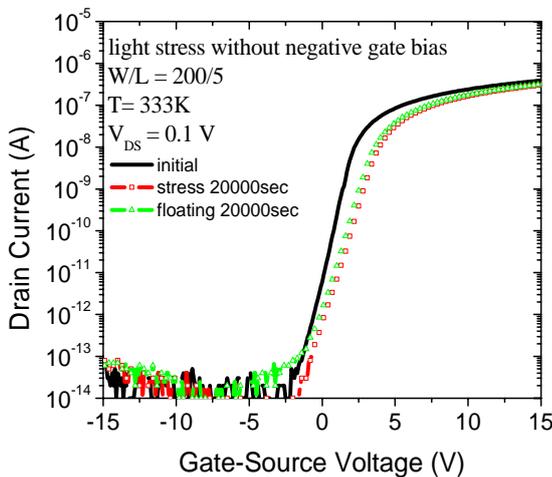


Figure.1 I-V transfer curve after light-induced stress without electrical gate bias

As shown in figure 2, V_{TH} was decreased from 1.28 V to -1.14 V after a-Si:H TFT was subject to -10V gate bias stress. However, S.S. was hardly changed. This result means that holes are trapped into gate insulator by negative gate bias stress [9]. This is because why the trapped holes

are formed as charge sheet so that those function as positive offset for the gate voltage. In the case of negative gate bias stress, the characteristic of self-recovery was experimented. As shown in figure 2, I-V transfer curve after keeping floating-state for 20000 seconds was recovered but not much. The results support that shallow-trapped charges at the interface between a-Si:H active layer and gate insulator may be released as time goes by. Therefore, the instability caused by negative gate bias stress has the different mechanism from that caused by light-induced stress.

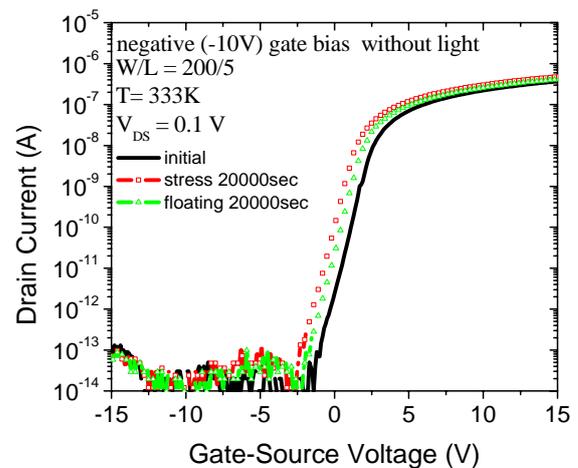


Figure 2 the I-V transfer curve of a-Si:H TFTs after negative gate bias stress without the light illumination

To support the mechanism of instability caused by negative gate bias stress, the negative gate bias stress was applied for 20000 seconds after only light-induced stress for 20000 seconds. Figure 3 shows that positively shifted V_{TH} caused by light-induced stress was negatively shifted without changing S.S. after negative gate bias stress without light illumination. This result means that the instability caused by negative gate bias stress is due to the trapped hole charges into gate insulator regardless of generated defect states caused by light-induced stress [9]. The trapped holes are formed as charge sheet so that those function as positive offset for the gate voltage. Therefore, negative V_{TH} shift in I-V transfer curve of a-Si:H TFT was observed while maintaining S.S. In addition, since trapped holes may be released as time goes by, self-recovery could happen as shown in figure 2. However, it is very difficult for deep-trapped charges to be fully recovered without thermal annealing.

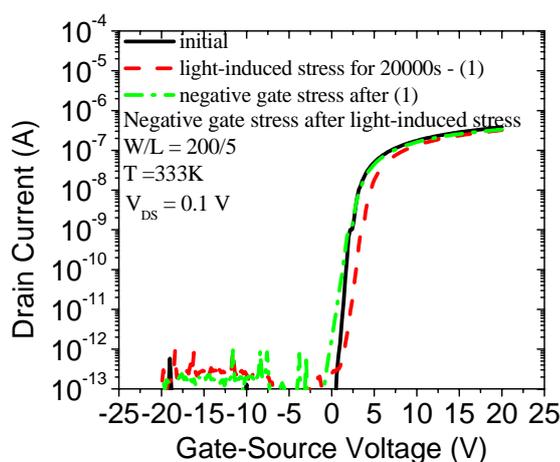


Figure 3 I-V transfer curve after negative gate stress on light-induced stressed a-Si:H TFT

To examine the effect of the light illumination under negative gate bias on the instability of a-Si:H TFTs, light-induced stress under negative (-10 V) gate bias was applied. Figure 4 shows that V_{TH} was decreased from 1.31 V to -3.70 V. The V_{TH} after negative gate bias stress with light illumination was more decreased than that after negative gate bias stress without light illumination. In other words, the instability caused by negative gate bias stress was enhanced due to the effect of light in spite of the different mechanism of the instability caused by the light-induced stress. It can be expected that the effect of light is related with the mechanism of instability caused by negative gate bias stress. In the case of negative gate bias stress under the light illumination, I-V transfer curve was more recovered as shown in figure 4 when compared with that in figure 2. It is induced that at first more hole charges were trapped at the interface during the stress due to the effect of light and naturally released during the floating time.

Light illumination increased carrier density when the light-induced stress was applied to a-Si:H TFTs [10-11]. At the same time extended hole-accumulation channel was formed by applied negative gate bias. Hence, the mechanism of charge trapping was promoted due to the increase of hole density in a channel region. This is because the increased holes in a channel region appertain to the source of the mechanism. It is concluded that larger V_{TH} shift caused by light-induced stress under negative gate bias results from the increase of hole density in a channel region by light illumination. The increase of carrier density in a channel region caused by the light illumination has the en-

hanced effect on the instability caused by negative gate bias stress.

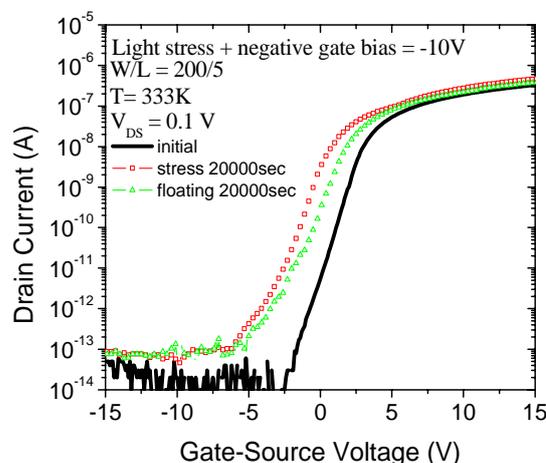
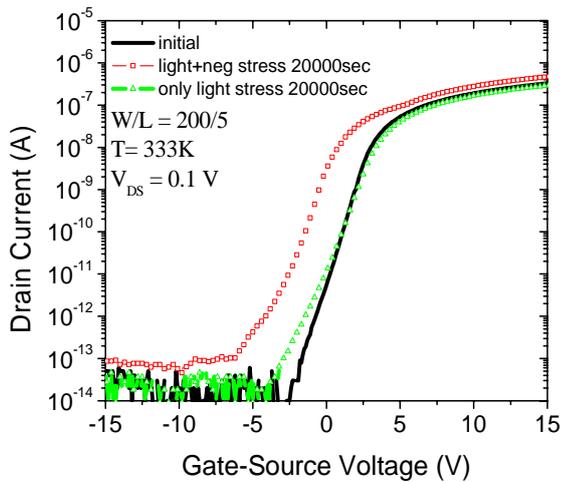


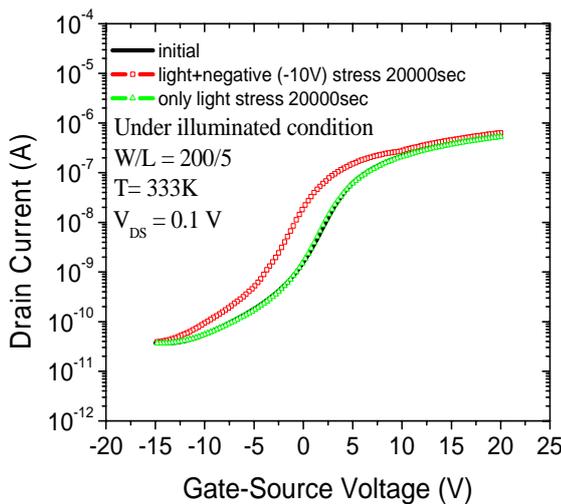
Figure 4 I-V transfer curve after negative (-10 V) gate bias stress with and without light illumination

As shown in figure 5, the prolonged light illumination led to the recovery of shifted V_{TH} caused by negative gate bias stress under the light illumination as thermal post-annealing treatment on stressed TFTs. The results in figure 5 were contrasted with those in figure 1, 2 and 4 which represent little self-recovery under the floating state. In other words, the effect of light on stressed a-Si:H TFT was observed as the recovery to initial state. This is because the recombination of even deep-trapped hole charges can be generated by the light illumination.

However, as shown in figure 5, increased S.S. caused by the light-induced stress was not improved even though shifted V_{TH} was recovered. It also supports that the effect of photo-induced quasi-annealing is connected with trapped hole charges caused by negative gate bias not generated defect states caused by light-induced stress. Hence, the instability caused by negative gate bias stress under the light illumination can be suppressed by using the effect of photo-induced quasi-annealing with time-division method on a-Si:H TFT based on photo-sensor applications as well as AMOLED displays.



a)



b)

Figure 5 the recovery of the instability after photo-induced quasi-annealing measured a) under the dark condition b) under the illuminated condition

CONCLUSION

We have investigated the effect of light on amorphous silicon thin film transistors based photo-sensor applications. We have analyzed the instability caused by electrical gate bias stresses under the light illumination and the effect of photo-induced quasi-annealing on the instability. V_{TH} under the negative gate bias stress with light illumination was more decreased than that under the negative gate bias stress without

light illumination even though V_{TH} caused by the light-induced stress without negative gate bias was shifted positively. These results are because the increase of carrier density in a channel region caused by the light illumination has the enhanced effect on the instability caused by negative gate bias stress. The prolonged light illumination led to the recovery of shifted V_{TH} caused by negative gate bias stress under the light illumination due to the recombination of trapped hole charges.

The investigation of the effect of light on a-Si:H TFTs can present physical characteristics of devices and limitation of operation when applied to the circuit design of photo-sensor applications. In particular, the instability caused by electrical gate bias under the light illumination can be overcome throughout the effect of photo-induced quasi-annealing.

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